POSSIBILITIES FOR MAINTAINING AA AND PP CAPABILITIES IN PARALLEL WITH ERHIC

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QUESTIONS TO ANSWER IN THIS TALK

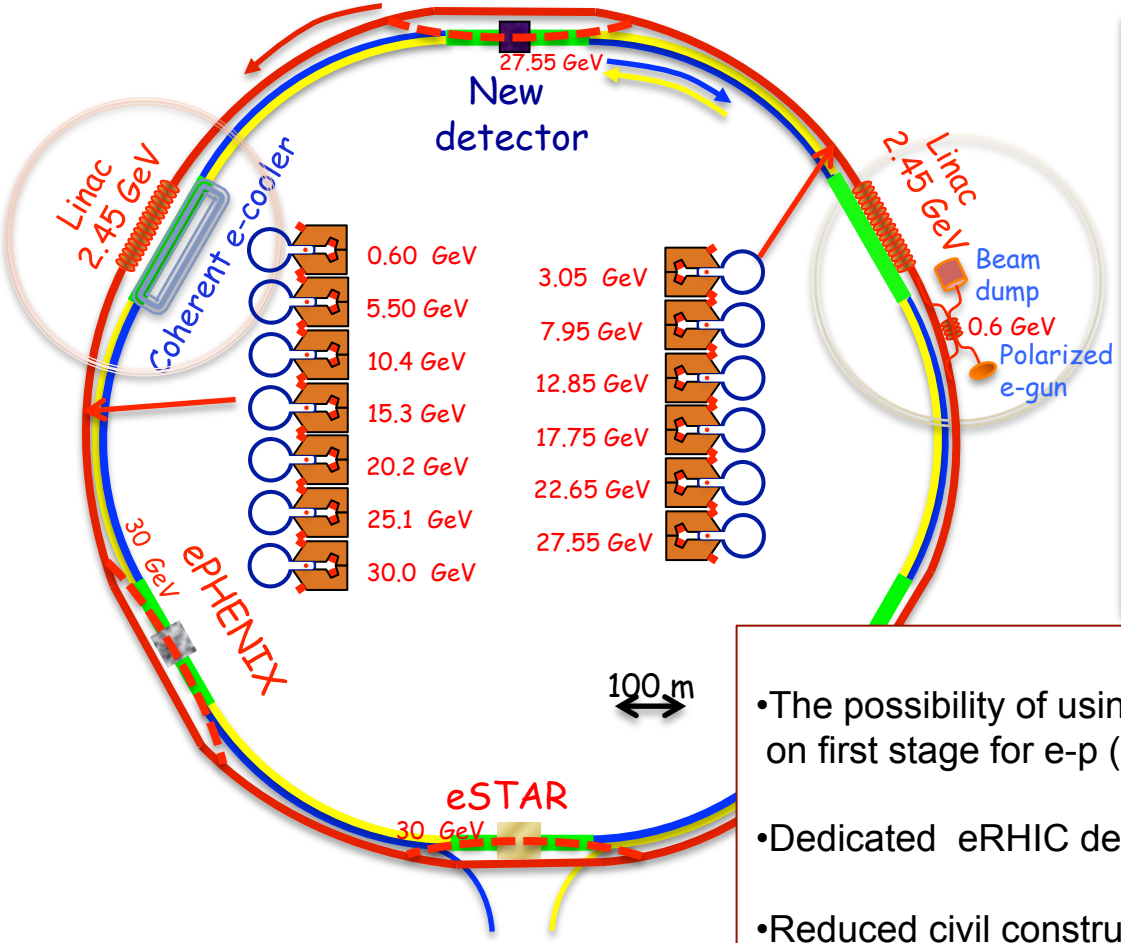
1. **Can one interaction region design satisfy operation conditions for both ion-ion and e-ion operation modes?**

2. **What would it take to switch between the e-ion and ion-ion operations in the eRHIC era?**

3. **Is simultaneous operation with e-ion and ion-ion collisions possible? How the luminosity is affected by the simultaneous operation?**

e-RHIC is a triple IP collider

5 to 30 GeV e^- x 325 GeV p - 130/u Au



✓All-in tunnel staging approach uses two energy recovery linacs and 6 recirculation passes to accelerate the electron beam.

✓Staging: the electron energy will be increased in stages, from 5 to 30 GeV, by increasing the linac lengths .

- The possibility of using upgraded STAR and PHENIX detectors on first stage for e-p (e-Au) collisions. (eSTAR and ePHENIX)
- Dedicated eRHIC detector can be added at IR12.
- Reduced civil construction cost

POLARIZED E-P LUMINOSITIES IN 10^{33} CM^{-2} S^{-1} UNITS

	Protons						
Electrons	E, GeV	**50**	**75**	**100**	**130**	**250**	**325**
	5	0.077	0.26	0.62	1.4	9.7	15
	10	0.077	0.26	0.62	1.4	9.7	15
	20	0.077	0.26	0.62	1.4	9.7	15
	30	0.015	0.05	0.12	0.28	1.9	3

Assumed limits: I_e = 50 mA, ξ_p =0.015, ΔQ_{sp} = 0.035

Main factors defining the relationship between e-ion and ion-ion operations

- **Interaction region design**

  Specific eRHIC IR requirements:

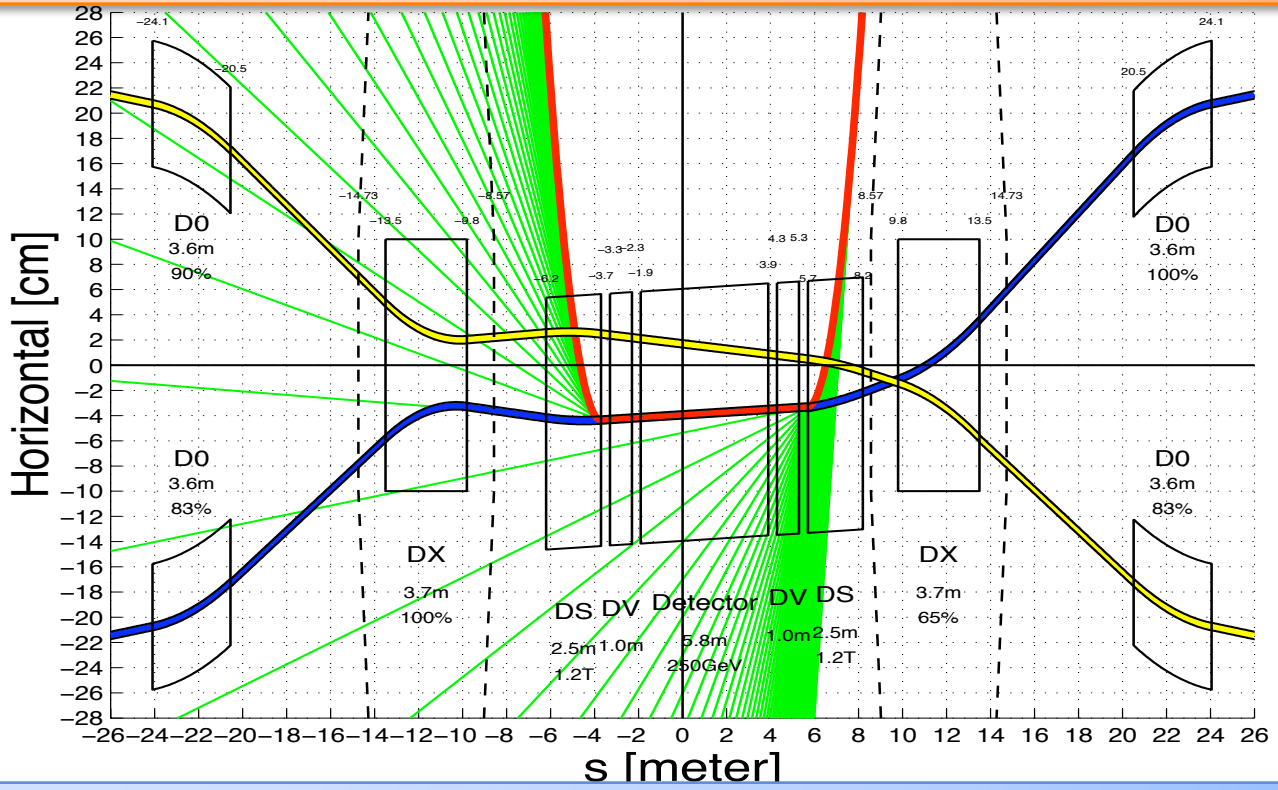
  - low β^*=5 cm
  - Wide energy variation range of both electron and ion beams
  - Synchrotron radiation protection of the detector

- **Luminosity**

  Luminosity reduction in the simultaneous operation mode.

IS SIMPLE IR UPGRADE POSSIBLE?

Can we add the electron beam line through the detector without affecting the present RHIC IR magnet arrangement ?



No! Even for 5 GeV energy the hard bending leads to unacceptable synchrotron radiation load around and in the detector.

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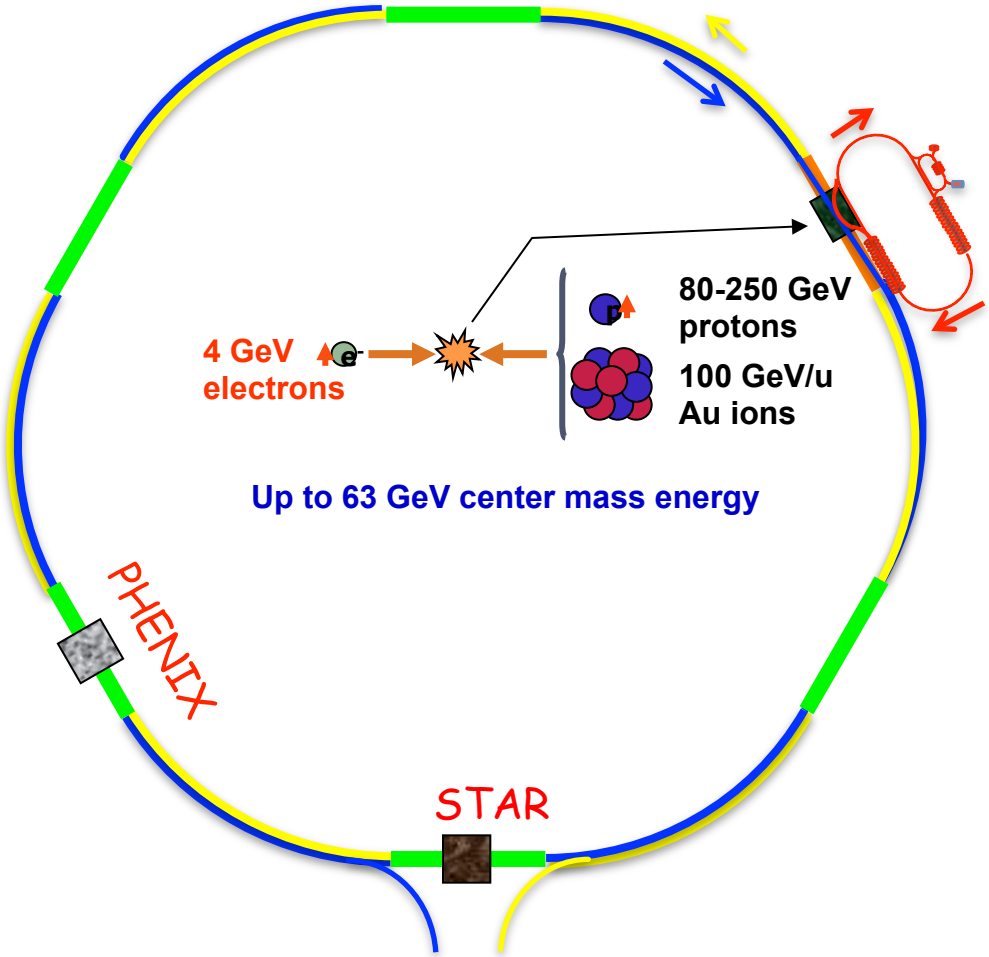
MeRHIC

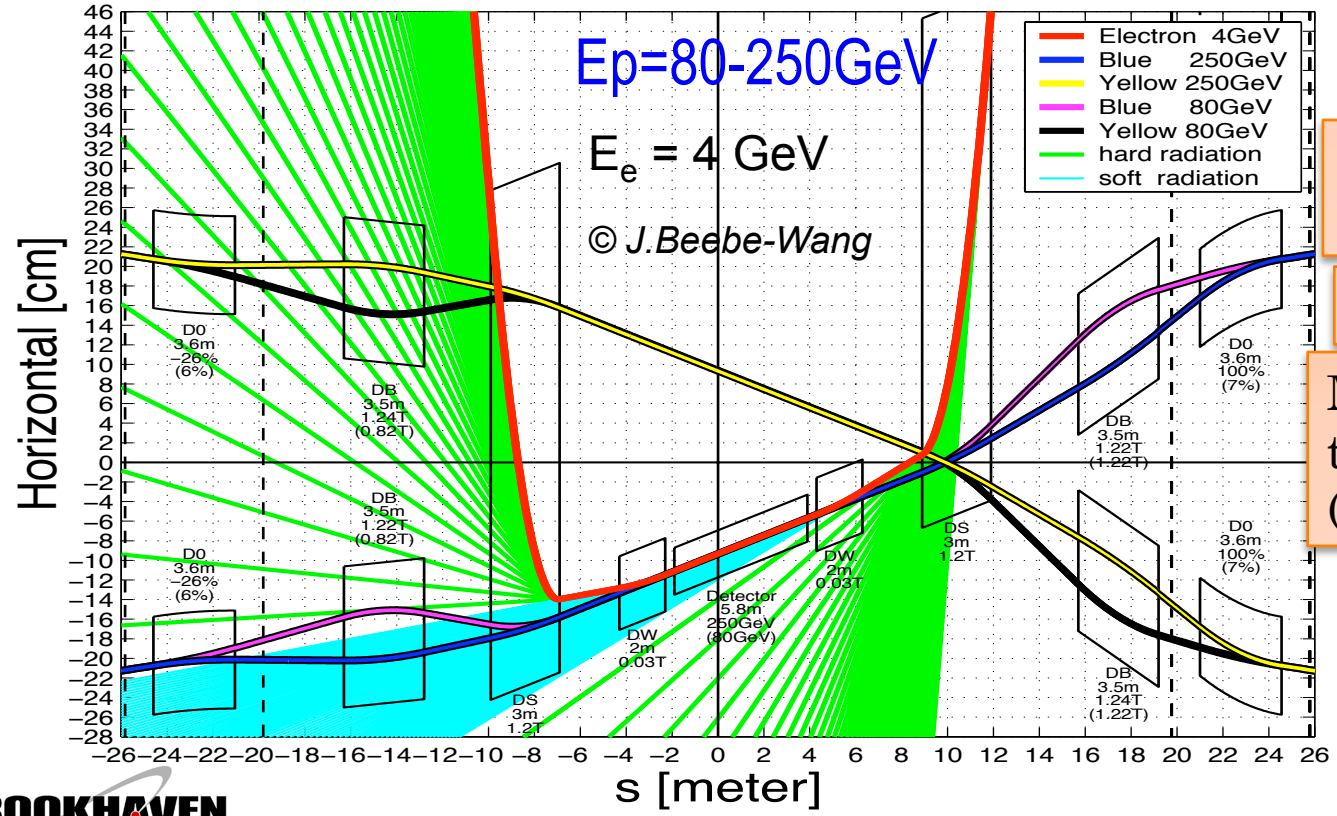


- MeRHIC – Medium energy eRHIC .
- Its design was developed in 2009 as possible first stage of the electron-ion collider at BNL.
- Fixed electron energy of 4 GeV.
- Electron acceleration is based on energy-recovery linacs.
- Parallel operation with the p-p (or ion-ion) collisions at PHENIX and STAR detectors.

MERHIC INTERACTION REGION

Minimal modifications of RHIC IR: only DX magnets are removed

Double stage electron beam bending scheme:
"soft" radiation dipole DW -> nearest to the detector; the radiation can not penetrate through the detector beam pipe
"hard" radiation dipole DS -> further away from the detector; the radiation does not get into the detector



The quadrupoles are far away from the IP

β^*=50 cm

Max luminosity up to 9 10^{32} cm^{-2} s^{-1} (with the cooling)

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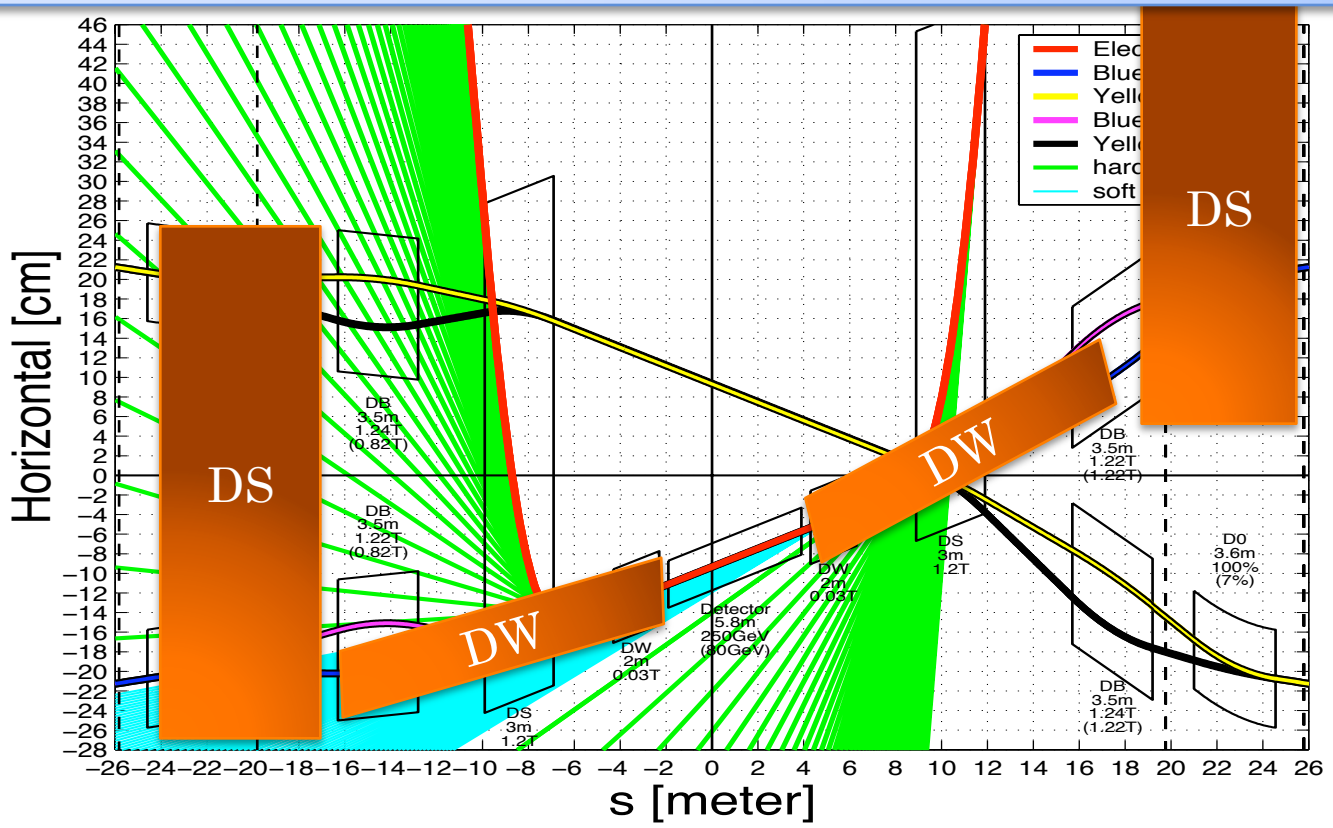
CAN MERHIC APPROACH WORK AT ELECTRON ENERGIES OF 10 GEV AND HIGHER?

Even at 10 GeV the MeRHIC approach affects the area of present D0 magnets and triplets.
Three beams through the detector arrangement becomes not possible.



$\text{Length}_{DW} \sim E^{3/2}$

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DEDICATED IR FOR ERHIC

- ✓Concentrating only on two beams passing through the detector: Blue ion beam and electrons

- ✓Present RHIC IR magnets: DX, D0, Q1,Q2,Q3 have to be removed and replaced by other magnets

- ✓The ion focusing triplets can be placed as close to the IP as 4.5m.
  The eRHIC luminosity 10^{33}-10^{34} cm^{-2} s^{-1} can be achieved.

- ✓No common dipoles; The fast beam separation done due to 10mrad crossing angle.

- ✓Two stage (soft-hard) bending scheme is preserved for the electron beam, but the bending magnets are placed far away from the IP. The soft bending is distributed over the distance of ~60m.
  The electron energy up to 30 GeV!

- ✓Additional important advantages:
  - oEasy to vary the beam energies in wide ranges.
  - oEasy to accommodate the detector requirements for forward momentum collision products

ERHIC HIGH-LUMINOSITY IR WITH β*=5 CM

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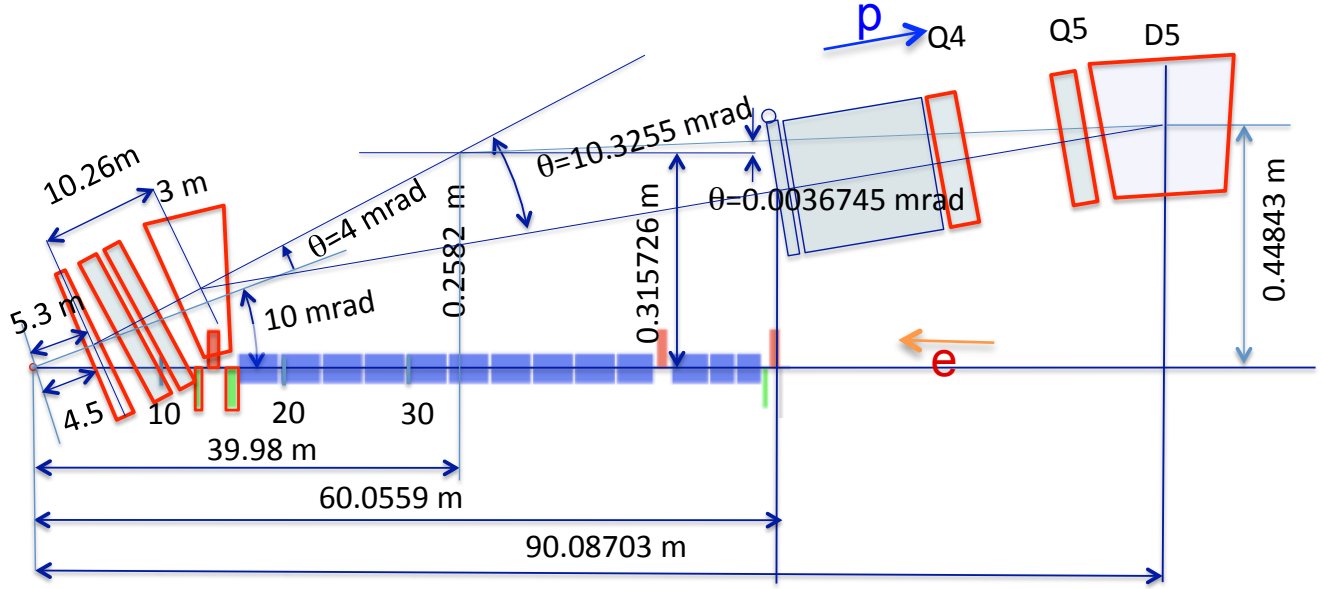
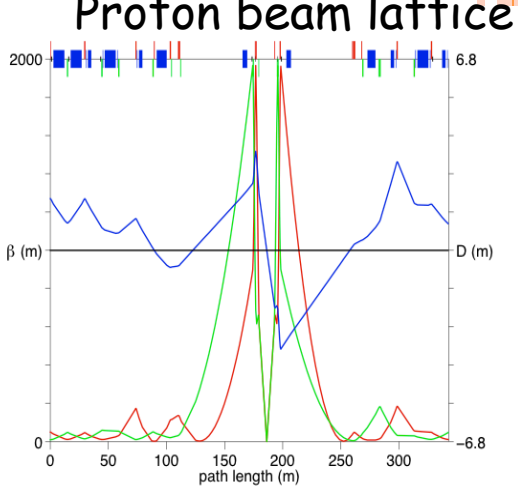




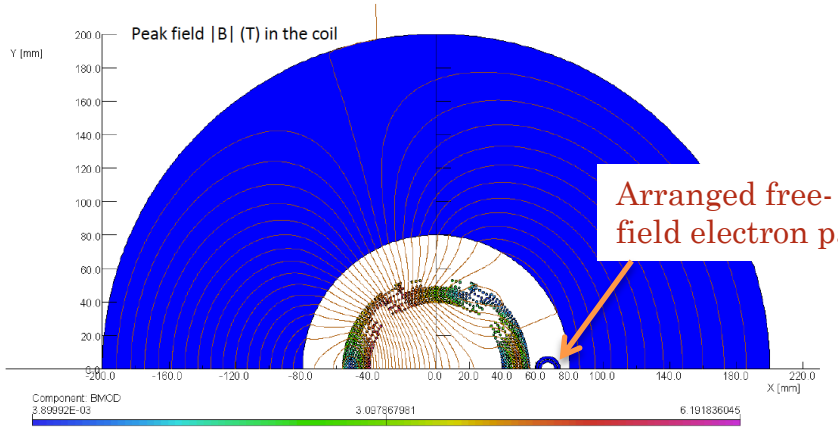
- 10 mrad crossing angle and crab-crossing
- High gradient (200 T/m) large aperture Nb_3Sn focusing magnets
- Gentle bending of the electrons to avoid SR impact in the detector

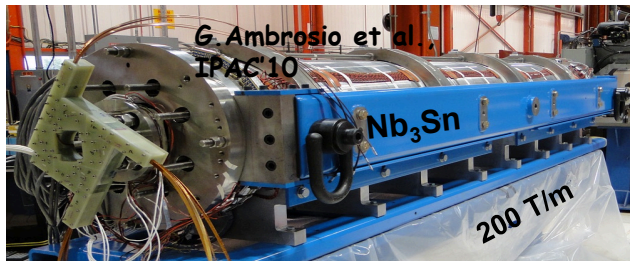
The design is not compatible with parallel operation with p-p (ion-ion) collisions.
There is no Yellow ion beam line through (or around) the detector area in the present design

TECHNICAL CHALLENGES OF THE IR DESIGN

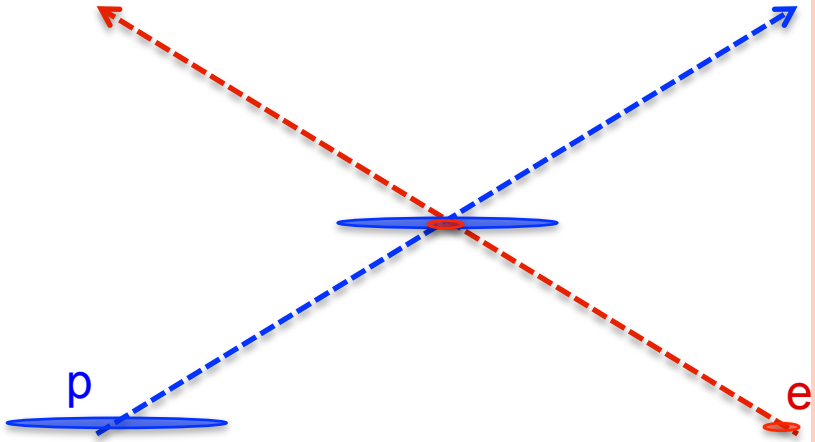
IR magnet design

eRHIC IR Combined Function Magnet, 07-Mar-2011, B. Parker (1/3)





Crab-crossing



- Superconducting cavities design
- Beam dynamics studies

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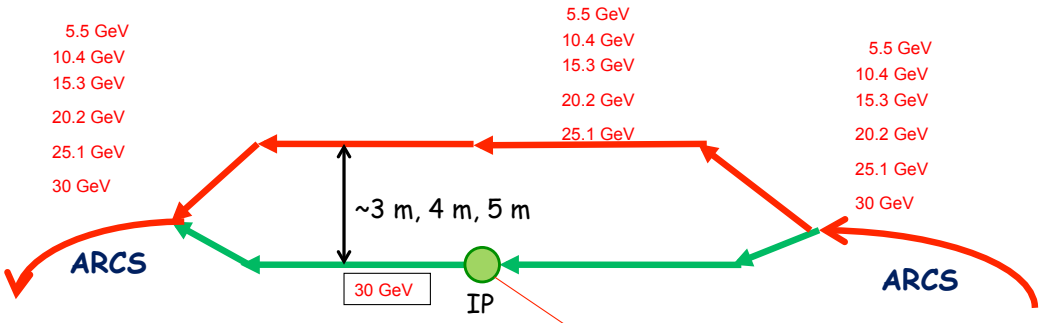
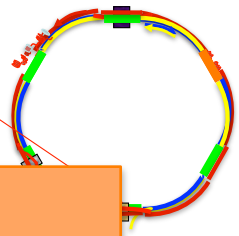
ELECTRON BY-PASS BEAM LINE AROUND DETECTORS



Line Displ.	Half-Line
5 m	3DBB_Right + 3DBB_Left + 4DBB_NoBend
4 m	2DBB_Right + 1DBB_NoBend + 2DBB_Left + 5DBB_NoBend
3 m	1DBB_Right + 2DBB_NoBend + 2DBB_Left + 5DBB_NoBend



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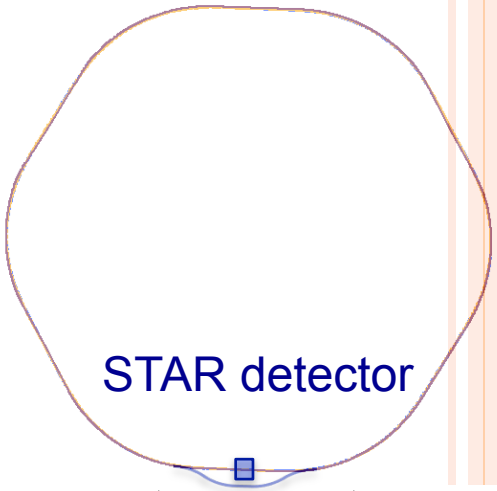
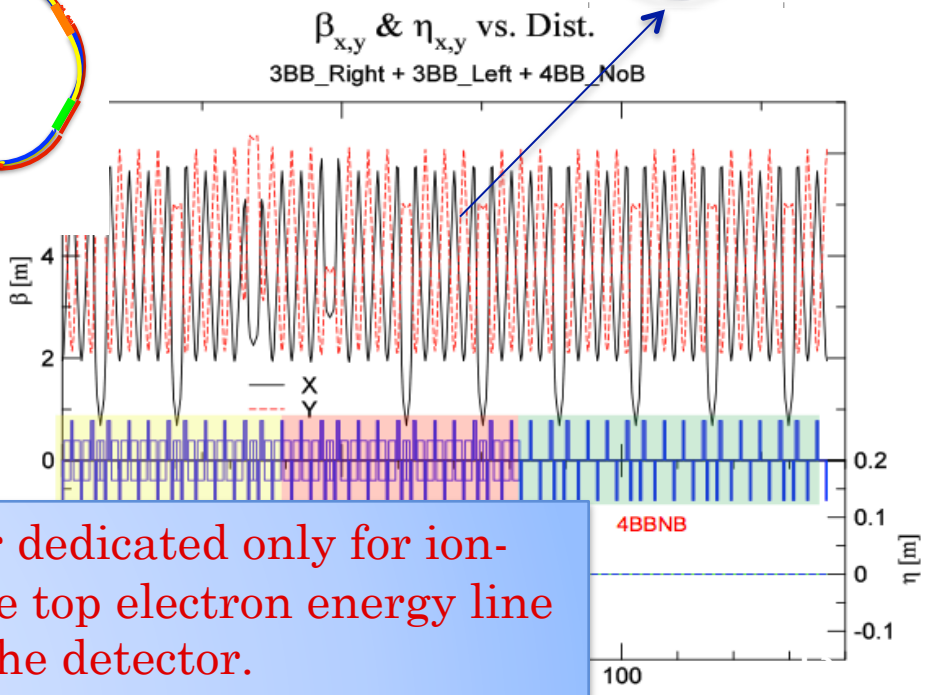




- Top energy line goes through the detector
- Other beam lines make excursion around the detector
- The variants of by-pass lines with 3, 4 and 5 m excursions have been developed

For the detector dedicated only for ion-ion collisions the top electron energy line also by-passes the detector.

General principles of the operation in different modes in eRHIC era

- Separate running with e-p (ion) and p-p (ion-ion) collisions.

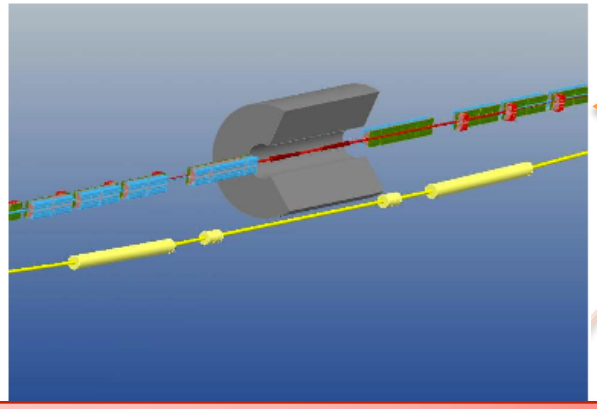
  Say, 1-2 long runs (years) of ion-ion then 1-2 long runs (years) of electron-ion operation.

- To switch from e-ion to ion-ion operation (and vice versa) between the runs the IR magnet lines from Q4 to Q4 have to be replaced.

- The details and the cost of such engineering solution to be evaluated.

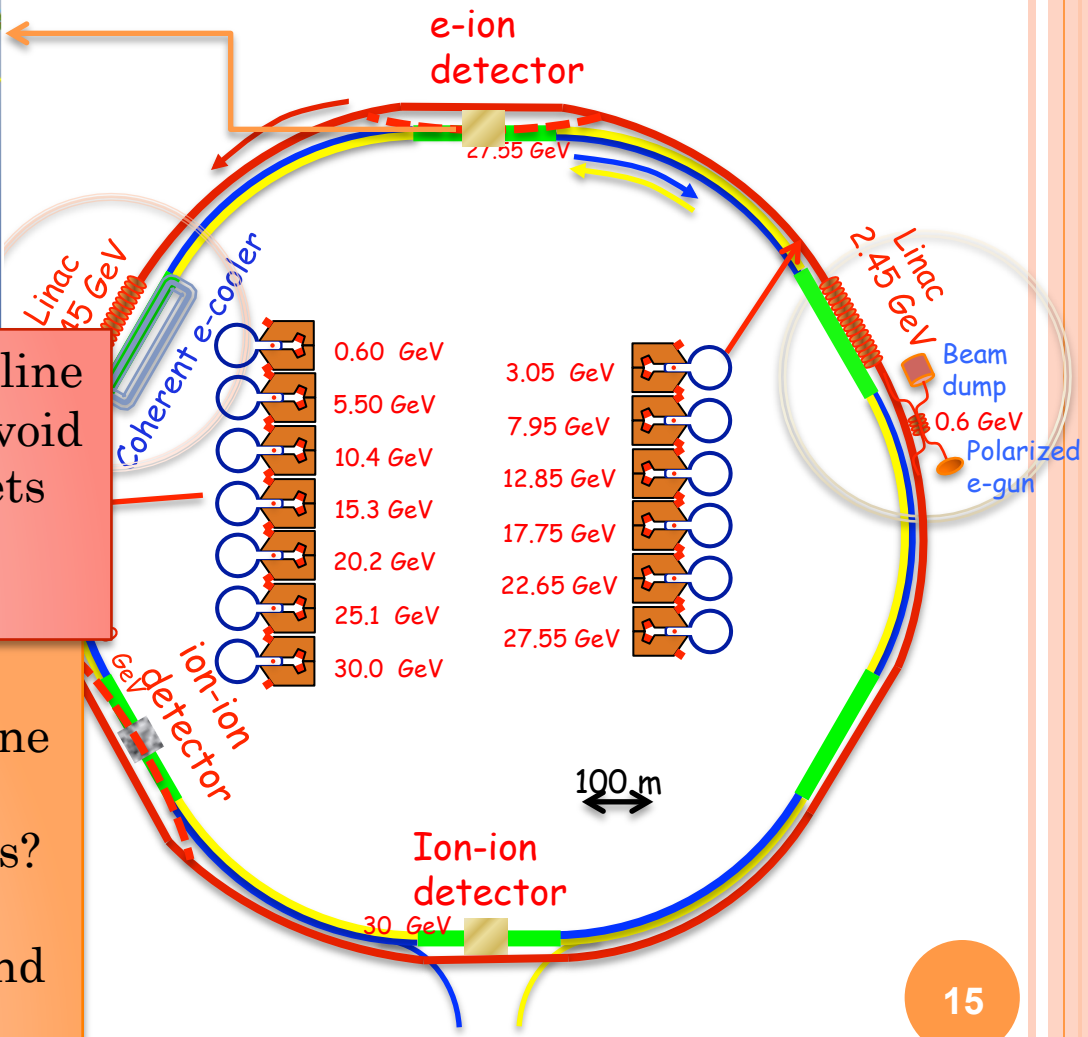
  This would be a part of the eRHIC cost estimate work to be completed to the end of the year.

CASE OF SEPARATE PURPOSE DETECTORS



Using the Yellow ion beam by-pass line around the e-ion detector one can avoid moving and replacing the IR magnets when switching operation modes.

- Can the Yellow ring by-pass line can be realized?
- What is the cost of such bypass?
- The solution for equalizing circumference length of Blue and Yellow rings?



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LUMINOSITY REDUCTION AT SIMULTANEOUS OPERATION MODE

- The simultaneous operation with e-ion and ion-ion collisions is not possible with the present IR design (without Yellow ion beam by-pass line).
- Still it is interesting to see what would be the effect on the luminosity in the simultaneous operation, if, somehow, it would become possible.

eRHIC parameters for e-p collisions:

$N_e = 2 \cdot 10^{10}$, $N_p = 2 \cdot 10^{11}$,

$\varepsilon_p = 0.2$ mm·mrad, $\xi_p = 0.015$

RHIC parameters for p-p collisions (one IP):

$N_p = 2 \cdot 10^{11}$,

$\varepsilon_p = 2$ mm·mrad, $\xi_p = 0.015$

Can not operate with the "cooled" emittance of eRHIC

Can operate with the un-cooled emittance of RHIC, but the e-p luminosity drops by at least factor 10.
Additional luminosity reduction (by factor 1.5) is due to reduced bunch frequency (9 MHz instead of 14 MHz)

Combined effect of e-p and p-p collisions on Blue beam is not clear and has to be studied

CONCLUSIONS

1. **Can the interaction region design satisfy operation conditions for both ion-ion and e-ion operation modes?**

   Presently it can't. The dedicated IR design for eRHIC is required to reach high luminosity, large energy variation ranges and has other numerous advantages. The present IR design does not contain the Yellow beam pass through or around the detector.

2. **What would it take to switch between the e-ion and ion-ion operations in the eRHIC era?**

   The IR magnets has to be replaced every time one switches between operations modes

3. **Is simultaneous operation with e-ion and ion-ion collisions possible? How the luminosity is affected by the simultaneous operation?**

   In present design the simultaneous operation is not possible. If it would be possible, the luminosity of the e-p collisions will be reduced at least by factor 15.